Kepler

A Search For Terrestrial Planets

Importance of Planet Detection:

The centuries-old quest for other worlds like our Earth has been rejuvenated by the intense excitement and popular interest surrounding the discovery of giant planets like Jupiter orbiting stars beyond our Solar System. The challenge now is to find planets which are 30-600 times less massive than Jupiter. **The *Kepler Mission* is specifically designed to survey the extended solar neighborhood to detect and characterize hundreds of Earth-size and larger planets in or near the habitable zone.**

Kepler Mission Science Objectives:

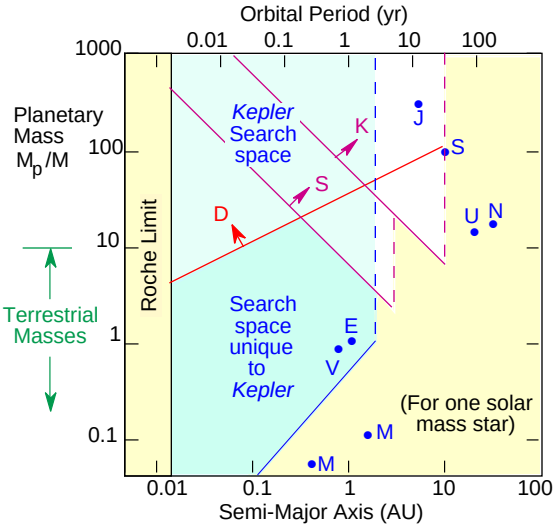
The scientific goal of the *Kepler Mission* is to explore the structure and diversity of planetary systems. This is achieved by surveying a large sample of stars to:

1) Determine the frequency of 0.8 R and larger planets in or near the habitable zone of a wide variety of spectral types of stars;
2) Determine the distributions of size and semi-major axis of these planets;
3) Estimate the frequency of planets orbiting multiple-star systems;
4) Determine the distributions of semi-major axis, eccentricity, albedo, size, mass, and density of short-period giant planets;
5) Identify additional members of each photometrically discovered planetary system using complementary techniques;
6) And determine the properties of those stars that harbor planetary systems.

The *Kepler Mission* also supports the objectives of the Origins theme missions, SIM and TPF.

Mission Overview:

Transits by terrestrial planets produce a fractional change in stellar brightness of 5×10^{-5} to 40×10^{-5} lasting for 4 to 16 hours. The orbit and size of the planets can be calculated from the period and depth of the transit. The proposed instrument is a one-meter aperture differential photometer with a 84 square degree field of view. It continuously and simultaneously monitors the brightnesses of 100,000 main-sequence stars brighter than 14th magnitude. The photometer must be spaceborne to obtain this precision and to avoid interruptions caused by day-night and seasonal cycles.



The Search Space for the *Kepler Mission*

Spacebased photometry is the only currently feasible method capable of detecting and characterizing terrestrial planets.

D: Doppler spectroscopy Δv sini>3m/s.
S: SIM with Δq>2 μarcsec @ 10 pc.
K: Keck with Δq>20 μarcsec @ 10 pc.

Expected Results:

Based on the assumptions described below, the following results are expected:

From transits of terrestrial planets
- About 175 Earth-size planet detections
- About 425 large-terrestrial planet detections
- About 70 cases (12%) of two or more planets per system

From modulation of the reflected light of giant inner planets:
- About 1700 planets with periods ≤ 1 week

From transits of giant planets:
- About 200 inner-orbit planet detections, along with their albedos
- Densities for 20 planets
- About 30 outer-orbit planet detections

Assumptions to be Tested:

The expected results described above are based on the following assumptions:

- Most main-sequence stars have terrestrial planets in or near the habitable zone;
- On average, *two Earth-size* planets form in the region between 0.1 and 3 AU, based on our Solar system and the accretion model of Wetherill; And
- The white-light variability of most solar-like stars *on the time scale of a transit* is similar to that of the Sun.

The *Kepler Mission* is designed to test these hypotheses, given the following:

- Monitoring of 100,000 main-sequence stars;
- Four years of observing; And
- A 1/2% transit probability per planet in or near the habitable zone.

Education, Technology and SDB:

All team members are participating in the EPO program; leveraging their institutional experience and capabilities for the *Kepler Mission* to produce an array of EPO products. This mission uses commercially available technology without requiring any new development. NASA Ames and Ball Aerospace both have a record of exceeding SDB goals and will do likewise for this mission.

Flight System Characteristics:

Photometer:	1-m aperture
Primary mirror:	85% lightweighted
Detectors:	21 - 2048^2 CCDs
Instrument noise level	$<1x10^{-5}$
Total noise, m_V=12 solar-like star (1σ):	$2x10^{-5}$
Data rate:	64 MBytes/day

No mechanisms besides antenna gimbals.

Spacecraft and instrument budgets:

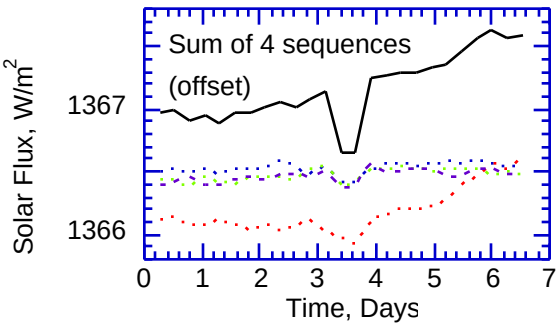
Mass:	730 kg plus 10% margin
Power:	406 W plus 30% margin

Mission Characteristics:

Delta II 7425 launch vehicle.
Earth-trailing heliocentric orbit.
Continuously point at one star field.
Monitor 100,000 main-sequence stars for transits of terrestrial or larger planets.
Mission lifetime of 4 years.
Deep Space Network for telemetry.

Schedule:

Concept study	11/98 to 3/99
Phase A/B	6/99 to 6/00
Phase C/D	6/00 to 6/03
Launch	5/03
Phase E	6/03 to 6/07
Educational program	6/99 to 6/07



Simulated Transits:

Signal of a terrestrial planet (1.0 $R_{\approx}$) with solar variability, realistic detector noise and shot noise. The top curve is the sum of the data (offset) for four transits.

Mission Team:

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Proj. Manager: L. Webster, NASA Ames
Science team members :

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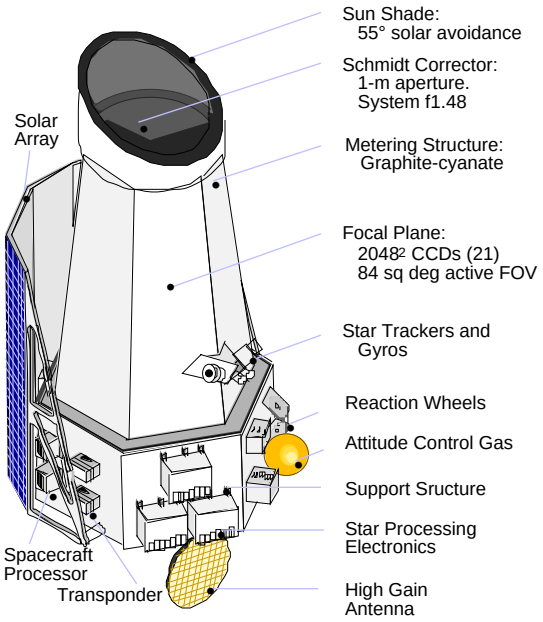
G. Benedict, W. Cochran	Univ. Texas-Austin

Industrial partner: Ball Aerospace

This is not an approved NASA mission. 6/98



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